

Intercropping – A Substantial Component in Sustainable Organic Agriculture

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ABSTRACT

The greatest challenge of the 21st century in many developing countries are to produce more and more basic necessities namely food, fodder, fuel and fibre for ever increasing human and animal population from the limited available land. The availability of land for agriculture is shrinking every day as it is increasingly utilized for non-agricultural purposes. Under this situation, one of the important strategies to increase agricultural output is development of high intensity cropping systems including intercropping system which involves biotic and abiotic stress resistant, soil building, protein rich and oil producing crops. Intercropping is a ways to increase diversity in an agricultural ecosystem. This review summarizes the most important aspects of intercropping system in organic agriculture.

Keywords: Intercropping, Stress resistant, Agricultural ecosystem, Diversity

INTRODUCTION

Sustainable agriculture is a type of agriculture that is more efficient in use of resources, for the benefit of human, and is in balance with the environment. In other words, sustainable agriculture must be ecologically appropriate, economically justified and socially desirable. One of the key strategies in sustainable agriculture is restoration diversity to agricultural ecosystems, and its effective management. Intercropping is a ways to increase diversity in an agricultural ecosystem. Intercropping as an example of sustainable

agricultural systems following objectives such as: ecological balance, more utilization of resources, increasing the quantity and quality and reduce yield damage to pests, diseases and weeds. Restoring on-farm biodiversity through diversified farming systems that mimic nature is considered to be a key strategy for sustainable agriculture. On-farm biodiversity, if correctly assembled in time and space, can lead to agro-ecosystems capable of maintaining their own soil fertility, regulating natural protection against pests, and sustaining productivity.

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Intercropping is an age old practice of growing simultaneously two or more crops on the same field such that the period of overlap is long enough to include vegetative stage (Gomez & Gomez, 1983). Intercropping has been a regular practice followed by the farmers of India, Africa, Sri Lanka and Malaysia. Intercropping is mainly practiced to cover the risk of failure of one of the component crops due to vagaries of weather or pest and disease incidence. Yield advantages in intercropping system are mainly because of differential use of growth resources by component crops. The complementarity will occur when the growth patterns of component crops differ in time.

Intercropping of legumes in association with non-legumes helps in utilization of nitrogen being fixed by legumes in the current growing season, but also helps in residual build up of nutrients in soil (Sharma

& Choubey, 1991). Best utilization of nutrients, moisture, space and solar energy can be derived through mixed/intercropping system.

Sarkar et al. (1995) reported that intercropping not only stabilizes crop production by reducing the impact of weather vagaries, but also increases cropping intensity considerably.

An enormous variety of intercropping systems exists, reflecting the range of crops and management practices farmers throughout the world use to meet their requirements for food, fiber, medicine, fuel, building materials, forage, and cash. Intercropping systems may involve mixtures of annual crops with other annuals, annuals with perennials, or perennials growing together and coexisting for a time (figure 1).



Fig. 1: Depending on the degree of both the spatial and temporal dimension of two (or more) crop species

Intercropping

Growing two or more crops simultaneously on the same field; crop intensification is in both temporal and spatial dimensions; there is intercrop competition during all or part o crop growth. Intercropping systems tend to be low

input, risk reducing under dry farming situations for crop diversification and ful fillment of subsistence objectives. At higher input levels it will be able to necessary to re evaluate and recombine various activities.

Eg. Groundnut + Redgram + Castor

Cotton + Black gram/green gram

Sorghum + Redgram

Types of intercropping

Mixed Intercropping

Growing two or more crops simultaneously with no distinct row arrangement. Also referred to as mixed cropping. The seeds of the crop varieties are mixed in desired proportion, sown and incorporated.

Eg. Grass legume mixture; Mixing the seeds of sorghum and cowpea in 5:1 ratio and broadcasted.

Row Intercropping

Growing two or more crops simultaneously where one or more crops are planted in rows; often referred to as intercropping.

Eg. Sorghum in paired rows intercropped with one row of cowpea

Planting 1 row of red gram for every 10 rows of groundnut

Strip Intercropping

Growing two or more crops simultaneously in different strips wide enough to permit independent cultivation but narrow enough for the crops to interact agronomically. Normally followed in sloppy lands and in soils prone for erosion.

Eg. Wheat and Bengal gram in alternate strips of 5-10 m

Relay Cropping

Growing two or more crops simultaneously during the part of the life cycle of each. A second crop is planted after the first crop has reached its reproductive stage of growth but before it is ready for harvest.

Eg. Broad casting black gram or green gram in the standing rice crop about 7-10 days before its harvest.

Advantages of intercropping in sustainable organic agriculture

Modification of microclimate

Intercropping practice could modify the microclimate by reducing light intensity, air temperature, desiccating wind and other climatic components. The emphasis of much previous work on intercropping temperate crops in the tropics was mainly on soil microclimate characterization and not on within-canopy microclimate. In the tropics,

where capital can be one of the major constraints in agricultural production, microclimate modifications that require high inputs such as the use of synthetic shade materials are not feasible (Jaya et al., 2001). Microclimate modification by cheap and simple means, such as intercropping might be acceptable as well as affordable. Maize is one of the row crops often selected for intercropping to provide shelter to understory crops because of its wide adaptation over a range of climates.

Insurance against crop failure

One important reason for which intercropping is popular in the developing world is that it is more stable than monocropping. The stability under intercropping can be attributed to the partial restoration of diversity that is lost under monocropping. For farmers who have limited resources, income and stability yield of agricultural systems is very important. From this point of view, intercropping provides high insurance against crop failure, especially in areas subject to extreme weather conditions such as frost, drought, flood, and overall provides greater financial stability for farmers, making the system particularly suitable for labor-intensive small farms. When several crops can be grown together, fail to produce a product, could be compensated by other crop, and thereby reduces the risk. Risk of agronomy failure in multi cropping systems is lower than pure cropping systems. It may be an appropriate growth condition for a species and inappropriate for other species (Eskandari et al., 2009).

Increasing production

One of the main reasons for the use of intercropping around the world is produced more than a pure cropping of same land amount (Caballero & Goicoechea, 1995). Ghanbari and Lee (2002) reported that dry matter production in wheat and beans intercrops had been more than their pure cropping. Odhiambo & Ariga, (2001) with maize and beans intercrops in different ratios found that production increased due to reduced competition between species compared competition within species. Wiley (1990)

considers intercropping as an economic method for higher production with lower levels of external inputs. This increasing use efficiency is important, especially for small-scale farmers and also in areas where growing season is short (Altieri, 1995). Production more in intercropping can be attributed to the higher growth rate, reduction of weeds, reducing the pests and diseases and more effective use of resources due to differences in resource consumption (Eskandari, 2012). In addition, if there are "complementary effects" between the components of intercropping, production increases due to reducing the competition between them (Mahapatra, 2011). Udhaya Nandhini and Latha (2014) reported that pigeonpea + greengram intercropping with different row ratios were found to increase the production. Pigeonpea + greengram with 1:3 row proportion gives 29% higher economic advantage over pure stands due to high resource use efficiency (Udhaya Nandhini & Latha, 2015).

Soil structure

Increased belowground biomass and root activity have a major impact on soil properties and on the soil solution. In maize/legume intercropping experiments, increased root activity has been shown to have positive effects on soil aggregation and to significantly

decrease dry bulk density and soil resistance to root penetration (Latif et al., 1992). Studies conducted by Carof (2006) revealed the role of a living cover crop root in maintaining soil structure and hydraulic conductivity over time. This author suggested that it can even provide long-term benefits. Even if explicit data on soil water content in cereal/legume intercropping is extremely rare, studies conducted by Celette et al. (2008) on intercropped vineyards showed that the soil water profile could be improved by reduced run-off and enhanced soil infiltration. The same results are assumed under cereal/legume intercropping.

Soil moisture

Water use efficiency is also another importance of intercropping system. Integration of legume either in sole or in the intercropping systems has the potentiality to extract more moisture from deeper soil surface. Intercropping with legumes is an excellent practice for controlling soil erosion and sustaining crop production. Sorghum-cowpea intercropping reduced runoff by 20-30% compared with sorghum sole crop and by 45-55% compared with cowpea monoculture. Moreover, soil loss was reduced with intercropping by more than 50% compared with sorghum and cowpea monocultures.



Fig. 2: Live mulch for moisture conservation

Soil erosion control

Plant cover in intercropping plays an important role in stopping energy from rainfall and prevent runoff which could cause soil erosion. Kariaga (2004) showed that in maize-cowpea cropping system, cowpea acts as a good cover and decreases run off than maize-bean system. Rana and Rana (2011) found that taller crops act as wind barrier for short crops, in intercrops of taller cereals with short legume crops. However, sorghum+cowpea cropping system decreases erosion by 20-30% than sorghum mono crop by 45-55% compared to cowpea monocrop. However, Kinama et al. (2007), Kinama et al. (2011) found that, intercropping maize senna and senna-cowpea reduced soil erosion compared to monocropped plots. Chen et al. (2010) observed that intercropping of wheat and potato grown in strips up to 5m can reduce wind erosion, soil desertification and degradation effectively. Deep roots penetrate far into the soil breaking up hardpans and use moisture and nutrients from deeper down in the soil. Shallow roots bind the soil at the surface and thereby help to reduce erosion and help to aerate the soil.

Canopy and relative humidity

Intercropping composed of different patterns of canopy development and different maturation times can display a greater amount of leaf area over the course of the growing season and intercept more total light energy than monocultures. Where polycultures produce earlier or later canopy, evaporation of soil moisture is reduced, weeds suffer from light and moisture competition, and there is decreased rain impact erosion through canopy filtering and greater root structures. Wilson and Ludlow (1991) reported soil temperatures up to 10°C cooler on forage under tree plantations in the tropics, assisting seedling survival, soil-water relations and possibly affecting the rate of litter breakdown and nitrogen mineralization.

Lodging resistance to prone crops

Lodging, which is commonly observed in some crops, frequently can reduce plant growth severely. Some of the damage is often

attributable to subsequent disease infections and mechanical damage, whereas loss of plant height reduces efficiency of light interception. Intercropping can provide better lodging resistance for some crops highly susceptible to lodging. The introduction of legumes intercropped with non-legumes has drawn considerable interest because not only is there the ability to improve cash returns by increasing land use efficiency, but the inclusion of component crops such as canola or mustard as an intercrop will also greatly improve lodging resistance of grain legumes, thereby increasing yield, product quality, and harvest efficiency.

Soil fertility

Conservation of soil fertility in intercropping is a form of rotation that each season is done on land. Cereal– grain legume intercropping has potential to address the soil nutrient depletion on smallholder farms. The legumes play an important role in nitrogen fixation (Peoples and Craswell, 1992), and are important source of nutrition for both humans and livestock. Rhizobium bacteria are able to have a symbiotic relationship with plants of leguminosae family and thereby can fixation of atmospheric nitrogen into available nitrogen for plants uptake and the result nitrogen (as an essential element for soil fertility and plant growth) is added to the soil. There are several reports indicating that increasing the nitrogen content in non-legume plants, due to the intercrops of these plants with plants of leguminosae family (Eskandari et al., 2009). In addition, the green parts and roots of the legume component can decompose and release nitrogen into the soil where it may be made available to subsequent crops. In particular, under low soil N conditions the advantages of legumes in an intercrop are greater (Lunnan, 1989). The benefits of a legume intercrop with respect to nitrogen are direct transfer of nitrogen from the legume to the cereal during the current intercrop and residual effects when the fixed nitrogen becomes available on the sequential crops after the senescence of the legume and the decomposition of residues. The direct transfer of nitrogen to companion

crops occurs mainly by excretion of nitrogen from the legume nodules, representing an immediate source of nitrogen to the cereal. Thus, the use of legumes in mixtures contributes some nitrogen to the cereal component and some residual nitrogen to the following crops. After the intercrop is harvested, decaying roots and fallen leaves provide nitrogen and other nutrients for the next crop (Lithourgidis et al., 2011). This residual effect of the pulse crop on the next crop is largest when the remains of the pulse are left on the field and ploughed after harvest (Rahman et al., 2009).

Legume Effect

The beneficial effects of the legumes in any crop rotation and intensive cropping system is termed as legume effect. N fixed by the intercrop of legume may be available to the associated cereal in the current growing season or as a residual N for the benefit of a succeeding cereal crop. Inclusion of legumes in the cropping systems is beneficial in many ways:

1. Legumes fix atmospheric nitrogen in root nodules and thus improve the nitrogen status of the soil.
2. It saves up to 25% of recommended level of nitrogen application to the associated cereals when grown as intercrop.
3. The crop residues and root nodules of legumes release nitrogen during decomposition for the use of the succeeding crop.
4. Legumes absorb soil phosphorus more efficiently and part of this mobilized phosphorus in organic form is available to the succeeding crop. It means legumes convert inorganic phosphorus into organic form of phosphorus and thus is able to extract insoluble forms of soil phosphorus.
5. Many of legumes can tolerate some amount of shading and drought.

Light interception/Light transmission ratio

Light interception and light use efficiency are powerful concepts for characterizing the resource capture and use efficiency of cropping systems, including intercrops. Improved productivity can result from either

greater interception of solar radiation, higher light use efficiency or a combination of the two (Willey, 1990). When total crop densities are higher in intercrops, they can intercept more light especially early in the growing season. Intercrops composed of non-synchronous patterns of canopy development and different maturation times can display a greater amount of leaf area over the course of the growing season and intercept more total light energy than monocultures.

Biru Amedie Yimam (2002) reported that higher light transmission ratio was observed in sole sorghum as compared to sorghum intercropped with legumes. Significantly lower light transmission was noticed in sorghum + groundnut system. Mohan (2003) reported that the performance of cropping system was enhanced when maize and legumes were intercropped as compared to their sole performance in study. Maize intercropped with legumes in 1:2 row proportion was superior in utilizing natural resources like light and moisture content.

Patil (2003) reported that the LTR and light interception differed significantly due to cropping system but not due to row proportions of little millet and pigeonpea. Significantly higher LTR and light interception values were recorded with sole pigeonpea in recommended spacing of 60 x 30 cm (40.18 and 59.82 per cent, respectively) and sole pigeonpea with 90 x 20 cm geometry (42.06 and 57.94 per cent, respectively) over sole little millet, little millet + relay horse gram and intercropped treatments mean. Sarika Jena et al. (2010) declared that the interception of PAR in sesame canopy was maximum in 4:1 row ratio of sesame + greengram intercropping. Utilisation of light use efficiency was highest in pigeonpea + greengram with 1:3 proportion (Udhaya Nandhini & Latha, 2015).

Pest control

Compared with monoculture, adding more plant species to a cropping system can affect herbivores in two ways. Firstly, the environment of the host plants, e.g. neighbouring plants and microclimatic

conditions, is altered and secondly, the host plant quality, e.g. morphology and chemical content, is altered (Langer et al., 2007). Habitat diversification makes the agricultural environment unfavourable for growth, multiplication and establishment of insect pest populations. The following are some approaches by which the pest population can be brought down. Intercropping or trap cropping system has been found favourable in reducing the population and damage caused by many insect pests due to one or more of the following reasons.

- Pest outbreak less in mixed stands due to crop diversity than in sole stands
- Availability of alternate prey
- Decreased colonization and reproduction in pests
- Chemical repellency, masking, feeding inhibition by odours from non-host plants.
- Act as physical barrier to plants.
- Trap crops attract insects and prevent the pests from reaching the target crop concentrating them in a particular area where they can be economically destroyed

Hence it is highly important that appropriate inter/trap cropping systems have to be evolved where reduction in pest level occurs. Sustainable systems of agricultural production are seen in areas where suitable crop rotation i.e. proper mixtures of crops and varieties are adopted in a given agro-ecosystem. For example growing rice after groundnut in garden land in puddled condition eliminates white grub.

Intercropping systems with greater diversity have the potential to reduce crop pests and increase the diversity of pollinators and natural enemies of crop pests. Intercropping maize in cotton fields increased the population of Araneae, coccinellidae and Chrysopidae by 62.8-115.7% compared with control fields. Maize also acted as a trap crop for *H. armigera* reducing the second generation eggs and damage to cotton (Wu et al., 1991). Intercropping pulses in cotton reduced the population of leaf hopper on

cotton (Rabindra, 1985) and Lablab bean in sorghum reduced the sorghum stem borer incidence. Intercropping upland rice with groundnut at low and medium populations of groundnut resulted in lower green stink bug (*Nezara viridula*) and stem borer (*Chilo zacconius*) infestations in rice compared with rice monoculture. This demonstrates that careful selection of crop combination and plant population could lead to reduced pest incidence in upland rice. Also, intercropping cowpea with cotton proved the best in suppressing the population of thrips and whiteflies, produced high yield, and was at par with the intercrops of cotton with marigold and cotton with sorghum. Hence it is highly important that appropriate intercropping systems have to be evolved where reduction in pest level occurs.

Weed control

Traditionally intercrops have been practiced to smother the weeds which depends mainly on crop behaviour and weed growth. Liebman and Dyck (1993) indicated that weed population density and biomass production may be markedly reduced using intercropping (spatial diversification). Intercrops may demonstrate weed control advantages over sole crops in two ways. First, greater crop yield and less weed growth may be achieved if intercrops are more effective than sole crops in usurping resources from weeds or by suppressing weed growth through alleopathy. Alternatively, intercrops may provide yield advantages without suppressing weed growth if intercrops use resources that are not exploitable by weeds or convert resources to harvestable material more efficiently than sole crops (Geno & Geno, 2001).

Lawson et al. (2006) reported that in maize-legume intercropping system, legume crops are generally suppressed by weeds and shade effect of corresponding maize crop which cause difference in photosynthetic efficiency of the two intercropped crops. Intercropping also encourages efficient utilization of the environmental resources (Egbe & Adeyemo, 2007); thus, the growths of weeds are decreased, depending on the

availability of environmental resources. Maize + legume intercropping is advocated because of the control of weeds and legume root

parasite infections (Fenandez et al., 2007) which ultimately may improve the soil fertility, crop yield and farmer's income.



Fig. 3: Calapogonium intercropping for weed control

Promotion of biodiversity

Intercropping is one way of introducing more biodiversity into agro-ecosystems and results from intercropping studies indicate that increased crop diversity may increase the number of ecosystem services provided. Higher species richness may be associated with nutrient cycling characteristics that often can regulate soil fertility. Intercropping of compatible plants promotes biodiversity by providing a habitat for a variety of insects and soil organisms that would not be present in a single crop environment. Stable natural systems are typically diverse, containing numerous different kinds of plant species, arthropods, mammals, birds, and microorganisms. As a result, in stable systems, serious pest outbreaks are rare because natural pest control can automatically bring populations back into balance (Altieri, 1995). Therefore, on-farm biodiversity can lead to agro ecosystems capable of maintaining their own soil fertility.

Resource use efficiency

The main aim of intercropping is to augment the total productivity per unit area and time, besides judicious and equitable utilization of

land resources and farming inputs including labour etc., Intercropping allows effective utilization of growth resources through crop intensification both in space and time dimensions. The conventional ways of intensifying crop production are vertical and horizontal expansions. Intercropping offers two additional dimensions, time and space.

Space dimension

The canopies of component crops may occupy different vertical layers with taller component tolerant to strong light and high evaporative demand and the shorter component favouring shade and high relative humidity Multi-storied cropping in coconut and planting shade trees in cocoa and tea plantations use this principle. Similarly, root systems of component crops may exploit the nutrients in different layers of soil and hence utilize the resources in a better way with much less competition.

Time dimension

When component crops of widely varying duration are planted, their peak demand for light and nutrients are likely to occur at different periods, thus reducing competition. In a combination having early and late maturing crops (sorghum + red gram), when

early maturing crops are harvested, conditions become favourable for the late maturing crop (red gram) to put forth its full vigour.

Thus, selection of crops that differ in competitive ability in time or space is essential for an efficient intercropping system as well as decisions on when to plant, at what density, and in what arrangement. Although in this way cropping management decisions specify the design of intercropping systems, intercrop performance is governed largely by the availability of and the competition for the environmental resources.

Other complementary effects

In an intercropping system involving a legume and a non-legume, part of the N fixed in the root nodule of the legume may become available to the non-legume component. With the presence of rhizosphere microflora and mycorrhiza, one species may lead to mobilization and greater availability of nutrients not only to the species concerned but also to the associated species. Provision of physical support by one species to the intercropped climbing species may improve the yield of the climber. Examples are coconut + pepper and maize + beans. The taller component acts as wind barrier protecting the shorter components from lodging.

CONCLUSION

From this review point of view it is very important to include intercropping systems with appropriate agronomic practices such as timely irrigation, pest protection and the likes to sustain the organic system.

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